

# Defining the Association between Diabetes and Plastic Surgery Outcomes: An Analysis of Nearly 40,000 Patients

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**Background:** Diabetes is an increasingly prevalent comorbidity in patients presenting for surgery, impacting nearly 14% of adults in the United States. Although it is known that diabetic patients are at an increased risk for postoperative complications, there is a paucity of literature on the specific ramifications of diabetes on different surgical procedures.

**Methods:** Using the American College of Surgeons National Surgical Quality Improvement Program dataset, demographics, outcomes, and length of in-patient hospitalization were examined for patients who underwent plastic surgery between 2007 and 2012. Adjusted multivariable logistic regression models were used to assess the relationship between diabetes status and a spectrum of medical and surgical postoperative outcomes.

**Results:** Thirty-nine thousand four hundred seventy-five plastic surgery patients were identified, including 1,222 (3.10%) with insulin-dependent diabetes mellitus (IDDM) and 1,915 (4.75%) with non-insulin-dependent diabetes mellitus (NIDDM), who had undergone breast, hand/upper and lower extremity, abdominal, or craniofacial procedures. Logistic regression analyses showed that only insulin-dependent diabetics had a higher likelihood of surgical complications (IDDM:  $P$  value  $< 0.0001$ ; NIDDM:  $P$  value  $< 0.103$ ), whereas patients with both IDDM and NIDDM had increased likelihoods of medical complications (IDDM:  $P$  value  $< 0.001$ ; NIDDM:  $P$  value = 0.0093) compared with nondiabetics. Average hospital stay for diabetics was also longer than for nondiabetics.

**Conclusions:** Diabetes is associated with an increase in a multitude of postoperative complications and in hospital length of stay, in patients undergoing plastic surgery. Diabetes status should thus be evaluated and addressed when counseling patients preoperatively. Risks may be further stratified based on IDDM versus NIDDM status. (*Plast Reconstr Surg Glob Open* 2017;5:e1461; doi: 10.1097/GOX.0000000000001461; Published online 17 August 2017.)

## INTRODUCTION

Diabetes mellitus is an increasingly prevalent comorbidity in the United States impacting 9.3% (29.1 million) of Americans, as estimated by the Centers for Disease Control and Prevention in 2014.<sup>1</sup> Alarming, 27.8% (8.1

million) of diabetic patients in the United States are undiagnosed. Additionally, approximately 30.0% (86 million) of Americans have prediabetes, and an estimated 15–30% of these prediabetic patients will develop type 2 diabetes mellitus within the next 5 years.<sup>1</sup> Thus, diabetes has a pervasive health care impact on the United States, and furthermore, a substantial economic burden, incurring costs of 245 billion dollars in 2012 alone.<sup>1</sup> In fact, diabetes has been reported as the leading contributor to inflation-adjusted increases in Medicare costs in the United States.<sup>2,3</sup> A robust body of research has established diabetes as a risk factor for a myriad of chronic illnesses.<sup>3–10</sup>

Comparatively, there is substantially less research examining whether diabetes is associated with poorer surgical outcomes.<sup>11–15</sup> It is known that diabetic patients are

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at an increased risk for postoperative complications, including infection.<sup>16–18</sup> Poor tissue perfusion, which results in inadequate antibiotic penetration and underlying immune compromise, is cited to contribute to an increase in complicated skin and soft-tissue infections in diabetic patients.<sup>17</sup> In terms of pathophysiology, polymorphonuclear lymphocytes are continually activated at baseline in hyperglycemic states and are thus deemed to be less responsive to infectious stimuli, thereby predisposing diabetic patients to surgical-site infections.<sup>17,19,20</sup> Additionally, increased levels of pro-inflammatory cytokines result in an insufficient immune response to pathogens as well as vascular inflammation, further contributing to poorer surgical outcomes.<sup>17,19,20</sup>

In plastic surgery, specifically, numerous clinical studies have substantiated that current diabetics are at higher risk of wound-related complications; however, the majority of this research has been conducted among patients undergoing breast reconstruction procedures.<sup>21–23</sup> To date, no known single study has examined the specific ramifications of diabetes mellitus on surgical outcomes for a range of plastic surgery procedures.

This study aims to identify how diabetes mellitus status (insulin-dependent diabetic, non–insulin-dependent diabetic, or nondiabetic) is associated with postoperative outcomes and wound-related complications in a full spectrum of plastic surgery procedures. It is the largest known study examining the link between diabetes mellitus and plastic surgery outcomes and uses data from the 2007–2012 American College of Surgeons National Surgery Quality Improvement Program (ACS-NSQIP) datasets.

## METHODS

### ACS-NSQIP Datasets

Data for the ACS-NSQIP datasets were collected by trained research nurses employed at participating institutions. For each patient, there were approximately 240 variables collected, including demographics, preexisting comorbidities, intraoperative variables, and outcomes affecting morbidity and mortality. Patients were contacted by letter or telephone 30 days after discharge to collect information on surgical-related outcomes up to this period. A complete list of the variables collected as part of ACS-NSQIP dataset is publicly available (<http://www.acsnsqip.org/>).

Data used in the current analyses were extracted from all plastic surgery procedures identified in the 2007–2012 ACS-NSQIP datasets. The 2012 Current Procedural Terminology (CPT) codes were used to identify these procedures.

### Dependent Variables

The dependent variables examined included a range of surgical complications: superficial wound infections, deep wound infections, organ space infections, wound dehiscence, pneumonia, reintubation, pulmonary embolism, urinary tract infection, postoperative bleeding/transfusion, graft or flap loss, deep venous thrombosis, sepsis, and return to operating room. Three composite

outcome variables “major surgical complications,” “medical complications,” and “wound complications” were created by combining certain specific outcomes. A “major surgical complication” comprised a deep wound infection, a graft/prosthetic loss, or an unplanned return to the operating room within the 30-day postoperative period. “Medical complications” included any of the following: pneumonia, pulmonary embolism, postoperative renal insufficiency (creatinine > 2 mg/dL), urinary tract infection, stroke, myocardial infarction, symptomatic deep vein thrombosis, or sepsis. “Wound complications” comprised superficial surgical-site infections, deep incisional wound infections, organ space infections, and wound dehiscence. “Wound infections” comprised superficial surgical-site infections and deep incisional wound infections.

### Independent Variables

The principal independent variable was the diabetic status of the patient at the time of the procedure. Patients were categorized as either insulin-dependent diabetic (IDDM), non–insulin-dependent diabetic (NIDDM), or nondiabetic. The ACS-NSQIP dataset defines a diabetic as an individual who has required a treatment regimen with exogenous parenteral insulin or oral antidiabetic agents for more than 2 weeks. Patients with insulin resistance who routinely take antidiabetic agents were also included. However, those whose diabetes was controlled by diet alone were not classified as diabetic in the current study. Of note, the laboratory value hemoglobin A1c is not a variable available or included within the ACS-NSQIP dataset.

### Statistical Analyses

The baseline sociodemographic and surgical characteristics of the sample were summarized using number and percentage in each group: IDDM, NIDDM, or nondiabetic.

Logistic regression models were used to examine associations between diabetic status and the various adverse outcomes. These analyses were adjusted for sex, race, age group, operation year, CPT code, body mass index (BMI), smoking, congestive heart failure, use of antihypertensives, renal failure, and dyspnea. The statistic of interest in these analyses was the odds ratios [95% confidence interval (CI)] and their *P* values of the IDDM and NIDDM groups compared with the nondiabetic group. Logistic regression was also used with an interaction term for CPT categories and the outcome variables to examine if diabetic status was associated with adverse outcomes for each of the CPT categories.

A negative binomial model was used for the hospital length of stay (LOS), adjusting for sex, race, age group, operation year, CPT code, BMI, smoking, history of congestive heart failure, use of antihypertensives, renal failure, and dyspnea. The statistics of interest were the least square mean values (95% CI), the rate ratio (95% CI), the *P* value for the test that each rate ratio was different from one, and the overall *P* value for the test that at least one of the rate ratios was different from one.

**RESULTS**

**Study Sample**

The baseline characteristics of the study sample as well as details of the surgeries performed are shown in Table 1. During the study period, 39,475 plastic surgery patients were identified who had undergone breast, hand/upper and lower extremity, abdominal, or craniofacial procedures. The cohort included 1,222 (3.10%) insulin-dependent diabetics and 1,915 (4.75%) non-insulin-dependent diabetics. In terms of baseline demographics, 32,239 patients (81.67%) were female, and 27,324 (69.22%)

were Caucasian. Age analyses showed that 50.09% of the patients were between 40 and 59 years of age at the time of surgery, as 9,578 (24.26%) were 40–49 years old, and 10,198 (25.83%) were 50–58 years old.

The majority of the procedures performed were breast procedures (61.84%). However, there was a representation of a wide range of plastic surgery procedures represented with 6.77% (2,671) autologous breast reconstruction, 18.46% (7,287) implant-based reconstruction, 17.31% (6,832) reduction mammoplasty, 19.46% (7,681) other breast procedures, 10.25% (4,045) hand/upper extremity procedures, 8.14% (3,212) abdominal procedures, 4.76% (1,880) craniofacial/head and neck procedures, 2.40%

**Table 1. Baseline Characteristics**

Variables	Statistic/Level	IDDM	NIDDM	Nondiabetic	Overall
		n (% of total)	n (% of total)	n (% of total)	n (% of total)
Sex	Female	768 (1.95)	1,387 (3.51)	30,084 (76.21)	32,239 (81.67)
	Male	450 (1.14)	526 (1.33)	6,206 (15.72)	7,182 (18.19)
	Unknown	4 (0.01)	2 (0.01)	48 (0.12)	54 (0.13)
Race	African American	214 (0.54)	258 (0.65)	3,455 (8.75)	3,927 (9.95)
	American Indian (or other)	8 (0.02)	15 (0.04)	90 (0.23)	113 (0.29)
	Asian	9 (0.02)	42 (0.11)	638 (1.62)	689 (1.75)
	Caucasian	850 (2.15)	1,336 (3.38)	25,138 (63.68)	27,324 (69.22)
	Hawaii Indian (or other)	3 (0.01)	5 (0.01)	74 (0.19)	82 (0.21)
	Hispanic	3 (0.01)	13 (0.03)	189 (0.48)	205 (0.52)
	Unknown	135 (0.34)	246 (0.62)	6,754 (17.11)	7,135 (18.07)
Age group (y)	16–19	3 (0.01)	3 (0.01)	524 (1.33)	530 (1.34)
	20–29	21 (0.05)	23 (0.06)	3,680 (9.32)	3,724 (9.43)
	30–39	79 (0.20)	98 (0.25)	5,521 (13.99)	5,698 (14.43)
	40–49	204 (0.52)	233 (0.59)	9,141 (23.16)	9,578 (24.26)
	50–59	339 (0.86)	591 (1.50)	9,268 (23.48)	10,198 (25.83)
	60–69	341 (0.86)	574 (1.45)	5,504 (13.94)	6,419 (16.26)
	70–79	176 (0.45)	290 (0.73)	1,938 (4.91)	2,404 (6.09)
	80–89	54 (0.14)	92 (0.23)	670 (1.70)	816 (2.07)
	90–99	5 (0.01)	11 (0.03)	92 (0.23)	108 (0.27)
BMI categories	< 18.5	17 (0.04)	6 (0.02)	674 (1.71)	697 (1.77)
	> 18.5 and < 25	172 (0.44)	221 (0.56)	12,651 (32.05)	13,044 (33.04)
	> 25 and < 30	276 (0.70)	491 (1.24)	11,633 (29.47)	12,400 (31.41)
	> 30	757 (1.92)	1,197 (3.03)	11,380 (28.83)	13,334 (33.78)
Smoker	No	1,016 (2.57)	1,664 (4.22)	30,652 (77.65)	33,332 (84.44)
	Yes	206 (0.52)	251 (0.64)	5,686 (14.40)	6,143 (15.56)
Dyspnoea	At rest	38 (0.10)	13 (0.03)	68 (0.17)	119 (0.30)
	Moderate	163 (0.41)	157 (0.40)	931 (2.36)	1,251 (3.17)
Use of antihypertensives	No	1,021 (2.59)	1,745 (4.42)	35,339 (89.52)	38,105 (95.53)
	Yes	290 (0.73)	544 (1.38)	27,830 (70.50)	28,664 (72.61)
History of congestive heart failure	No	932 (2.36)	1,371 (3.47)	8,508 (21.55)	10,811 (27.39)
	Yes	1,175 (2.98)	1,903 (4.82)	36,292 (91.94)	39,370 (99.73)
Renal failure (not requiring dialysis)	No	47 (0.12)	12 (0.03)	46 (0.12)	105 (0.27)
	Yes	1,193 (3.02)	1,908 (4.83)	36,321 (92.01)	39,422 (99.87)
Renal failure requiring dialysis	No	29 (0.07)	7 (0.02)	17 (0.04)	53 (0.13)
	Yes	1,124 (2.85)	1,894 (4.80)	36,261 (91.86)	39,279 (99.50)
Year of Procedure	2007	98 (0.25)	21 (0.05)	77 (0.20)	196 (0.50)
	2008	35 (0.09)	51 (0.13)	912 (2.31)	998 (2.53)
	2009	88 (0.22)	129 (0.33)	2,655 (6.73)	2,872 (7.28)
	2010	180 (0.46)	235 (0.60)	4,189 (10.61)	4,604 (11.66)
	2011	211 (0.53)	307 (0.78)	5,721 (14.49)	6,239 (15.80)
	2012	324 (0.82)	514 (1.30)	9,564 (24.23)	10,402 (26.35)
	2013	384 (0.97)	679 (1.72)	13,279 (33.68)	14,360 (36.38)
Type of procedure	Breast reconstruction—autologous	33 (0.08)	115 (0.29)	2,523 (6.39)	2,671 (6.77)
	Breast reconstruction—implant-based	90 (0.23)	220 (0.56)	6,977 (17.67)	7,287 (18.46)
	Reduction mammoplasty	75 (0.19)	278 (0.70)	6,479 (16.41)	6,832 (17.31)
	Other breast procedure	102 (0.26)	290 (0.73)	7,289 (18.46)	7,681 (19.46)
	Abdominal procedure	113 (0.29)	217 (0.55)	2,882 (7.30)	3,212 (8.14)
	Hand/upper extremity	117 (0.30)	192 (0.49)	3,736 (9.46)	4,045 (10.25)
	Lower extremity	158 (0.40)	80 (0.20)	708 (1.79)	946 (2.40)
	Craniofacial/head and neck	44 (0.11)	118 (0.30)	1,718 (4.35)	1,880 (4.76)
	Other	490 (1.24)	405 (1.03)	4,026 (10.20)	4,921 (12.47)

Analysis has been adjusted for sex, race, age group, operation year, CPT code, BMI, history of congestive heart failure, use of antihypertensives, renal failure (not requiring dialysis), renal failure requiring dialysis and dyspnea.

(946) lower extremity procedures, and 12.47% (4,921) other procedures. "Other" procedures included plastic surgery procedures such as aesthetic procedures; incision and drainage of hematoma; incision and drainage of seroma; foreign body removal; anastomosis of common sensory nerve in hand or foot; full-thickness skin graft in face, perineum, hand, or foot; free muscle or myocutaneous flap with microvascular anastomosis without defined location in the database; and all other procedures without defined location.

**Major Complications by Diabetic Status**

Overall, 8.34% (3,291) of patients experienced postoperative complications. The most common complications were wound-related, impacting 3.97% (1,566) of patients in the cohort (Table 2). Logistic regression analyses showed that only insulin-dependent diabetics had a higher likelihood of surgical complications [IDDM: odds ratio (OR), 1.78; *P* value < 0.0001; NIDDM: *P* value < 0.103], whereas both insulin-dependent and non-insulin-dependent diabetics had increased likelihoods of medical complications (IDDM: OR, 1.63; *P* value < 0.001; NIDDM: OR, 1.44; *P* value = 0.0093) compared with nondiabetics.

**Table 2. Logistic Regression Analysis of Major Complication Categories between Diabetics and Nondiabetics**

Parameters	n (%)	OR (95% CI)	<i>P</i>
Major medical complications*			
IDDM	95 (%1 = 13.46)	1.63 (1.22–2.14)	0.000647
NIDDM	71 (%2 = 10.06)	1.44 (1.09–1.89)	0.009304
Major surgical complications†			
IDDM	183 (%3 = 9.31)	1.78 (1.45–2.16)	<0.0001
NIDDM	140 (%4 = 7.12)	1.74 (0.96–1.42)	0.103763
Wound Complications‡			
IDDM	114 (%5 = 7.85)	1.53 (1.20–1.92)	0.000395
NIDDM	112 (%6 = 7.71)	1.19 (0.96–1.47)	0.111586

Analysis has been adjusted for sex, race, age group, operation year, CPT code, BMI, history of congestive heart failure, use of antihypertensives, renal failure (not requiring dialysis), renal failure requiring dialysis and dyspnea. %1 Is the proportion of patients with IDDM who encountered a major medical complication in the context of total incidences of major medical complications. %2 Is the proportion of patients with NIDDM who encountered a major medical complication in the context of total incidences of major medical complications. %3 Is the proportion of patients with IDDM who encountered a major surgical complication in the context of total incidences of major surgical complications. %4 Is the proportion of patients with NIDDM who encountered a major surgical complication in the context of total incidences of major surgical complications. %5 Is the proportion of patients with IDDM who encountered a wound complication in the context of total incidences of wound complications. %6 Is the proportion of patients with NIDDM who encountered a wound complication in the context of total incidences of wound complications.

\*Major medical complications included any of the following: pneumonia, pulmonary embolism, postoperative renal insufficiency (creatinine > 2mg/dL), urinary tract infection, stroke, myocardial infarction, symptomatic deep vein thrombosis, or sepsis.

†Major surgical complication comprised a deep wound infection, a graft/prosthetic loss, or an unplanned return to the operating room within the 30-day postoperative period.

‡Wound complications comprised superficial surgical-site infections, deep incisional wound infections, organ space infections, or wound dehiscence.

The odds of an insulin-dependent diabetic having a medical complication were 1.63 times (95% CI, 1.22–2.14; *P* value < 0.001) and a non-insulin-dependent diabetic was 1.44 times (95% CI, 1.09–1.89; *P* value = 0.0093) compared with a nondiabetic. The odds of insulin-dependent diabetics having a major surgical complication were 1.78 times (95% CI, 1.45–2.16; *P* value < 0.0001) that of nondiabetics. Having non-insulin-dependent diabetes was not significantly associated with major surgical complications (*P* value = 0.104; Tables 3–5).

**Analysis of Wound-Related Complications between Diabetics and Nondiabetics**

Insulin-dependent diabetic patients had a higher likelihood of wound complications (OR, 1.53; *P* < 0.001) than nondiabetic patients (Table 2). Having non-insulin-dependent diabetes was not associated with wound complications (*P* value = 0.112). The odds of patients with insulin-dependent diabetes having a wound complication was 1.53 times (95% CI, 1.20–1.92; *P* value < 0.001) that of nondiabetics.

More specifically, the odds of an insulin-dependent diabetic having wound dehiscence was 2.05 times (95% CI, 1.27–3.20; *P* value < 0.0023) that of a nondiabetic, and the odds of an insulin-dependent diabetic having a wound infection (which includes superficial wound occurrences as well as deep incisional surgical site infection occurrences) was 1.55 times (95% CI, 1.18–2.02; *P* value < 0.0012) that of a nondiabetic. Wound subgroup analyses further identified that having non-insulin-dependent diabetes was not significantly associated with wound dehiscence (*P* value = 0.8023) and wound infection (*P* value = 0.066; Tables 6, 7).

**Analysis of Hospital LOS between Diabetics and Nondiabetics**

Negative binomial model analyses revealed that the average LOS for insulin-dependent diabetics was 1.06 days

**Table 3. Logistic Regression Analysis of Wound-Related Complications between Diabetics and Nondiabetics**

Parameters	n (%)	OR (95% CI)	<i>P</i>
Wound dehiscence occurrences			
IDDM	21 (%1 = 10.31)	2.05 (1.27–3.20)	0.002253
NIDDM	19 (%2 = 7.25)	1.07 (0.63–1.71)	0.802341
Wound infection occurrences			
IDDM	85 (%3 = 7.28)	1.55 (1.18–2.02)	0.001246
NIDDM	88 (%4 = 7.53)	1.25 (0.98–1.58)	0.065958

Analysis has been adjusted for sex, race, age group, operation year, CPT code, BMI, history of congestive heart failure, use of antihypertensives, renal failure (not requiring dialysis), renal failure requiring dialysis and dyspnea.

%1 Is the proportion of patients with IDDM who encountered a wound dehiscence occurrence in the context of total incidences of wound dehiscence occurrences. %2 Is the proportion of patients with NIDDM who encountered a wound dehiscence occurrence in the context of total incidences of wound dehiscence occurrences. %3 Is the proportion of patients with IDDM who encountered a wound infection occurrence in the context of total incidences of wound infection occurrences. %4 Is the proportion of patients with NIDDM who encountered a wound infection occurrence in the context of total incidences of wound infection occurrences.



**Table 4. Logistic Regression Analysis of the Effect of IDDM on Major Complications following Plastic Surgery Procedures, Categorized According to CPT Grouping Classifications**

CPT Categorization	Surgical Complications			Wound Complications			Medical Complications		
	OR	95% CI	P	OR	95% CI	P	OR	95% CI	P
Breast reconstruction—autologous	0.713	0.281–1.465	0.414	0.518	0.113–1.36	0.83	1.765	0.5368–4.261	0.27
Breast reconstruction—implant-based	0.928	0.420–1.753	0.835	0.662	0.204–1.562	0.47	5.517 × 10 <sup>-6</sup>	NA, 0.0.0319	0.95
Reduction mammoplasty	1.304	0.461–2.874	0.561	0.881	0.375–1.731	0.65	1.764	0.0659–5.524	0.87
Other breast procedure	0.861	0.306–1.882	0.741	0.987	0.350–2.165	0.68	5.517 × 10 <sup>-6</sup>	NA, 0.583	0.96
Abdominal procedure	3.816	1.986–6.672	< 0.001	3.653	2.125–5.878	< 0.001	3.344	1.483–6.525	0.0012
Hand/upper extremity	4.638	2.242–8.589	< 0.001	5.364	2.456–10.361	0.0045	5.294	1.239–15.666	0.0076
Lower extremity	10.76	6.934–16.213	< 0.001	8.461	4.605–14.607	< 0.001	16.171	10.087–25.355	< 0.001
Craniofacial/head and neck	0.845	0.139–2.684	0.815	0.0000149	9.827 × 10 <sup>-5</sup> –0.00678	0.75	5.517 × 10 <sup>-6</sup>	NA, 0.00599	0.972
Other	8.74	6.966–10.877	< 0.001	6.611	4.854–8.843	< 0.001	8.526	6.165–11.584	< 0.001

NA, value of less than 10<sup>-10</sup>.

**Table 5. Logistic Regression Analysis of the Effect of NIDDM on Major Complications following Plastic Surgery Procedures, Categorized According to CPT Grouping Classifications**

CPT Categorization	Surgical Complications			Wound Complications			Medical Complications		
	OR	95% CI	P	OR	95% CI	P	OR	95% CI	P
Breast reconstruction—autologous	1.0434	0.593–1.694	0.87	1.379	0.745–2.327	0.27	1.0785	0.329–2.602	0.88
Breast reconstruction—implant-based	0.542	0.246–1.025	0.089	0.915	0.434–1.683	0.79	1.189	0.289–3.239	0.77
Reduction mammoplasty	1.374	0.648–2.553	0.36	1.237	0.715–1.987	0.411	2.157	0.515–6.111	0.21
Other breast procedure	0.907	0.429–1.668	0.77	0.728	0.286–1.506	0.45	1.109	0.180–3.638	0.89
Abdominal procedure	3.909	2.377–6.126	< 0.001	3.697	2.413–5.462	< 0.001	3.576	1.936–6.131	< 0.001
Hand/upper extremity	1.629	0.631–3.448	0.25	1.099	0.267–2.983	0.87	2.157	0.343–7.478	0.3
Lower extremity	2.389	1.204–4.278	< 0.01	1.733	0.604–3.924	0.24	1.765	0.615–3.999	0.23
Craniofacial/head and neck	1.237	0.434–2.761	0.64	1.42	0.344–3.907	0.56	6.471	2.344–15.454	< 0.001
Other	2.703	2.015–3.556	< 0.001	2.182	1.452–3.155	< 0.001	3.27	2.202–4.697	< 0.001

**Table 6. Logistic Regression Analysis of the Effect of IDDM on Wounds following Plastic Surgery Procedures, Categorized According to CPT Grouping Classifications**

CPT Categorization	Wound Dehiscence			Wound Infection		
	OR	95% CI	P	OR	95% CI	P
Breast reconstruction—autologous	0.888	0.0313–0.035	0.91	0.652	0.161–1.722	0.46
Breast reconstruction—implant-based	0.774	0.05–4.114	0.8	0.261	0.0148–1.168	0.18
Reduction mammoplasty	1.342	0.219–4.345	0.68	0.726	0.258–1.586	0.48
Other breast procedure	2.082	0.336–6.915	0.32	0.84	0.207–2.230	0.77
Abdominal procedure	5.032	1.712–11.898	< 0.001	3.657	2.004–6.157	< 0.001
Hand/upper extremity	5.032	0.266–29.485	0.13	4.945	2.031–10.308	< 0.001
Lower extremity	7.547	2.792–17.341	< 0.001	10.719	4.954–21.313	< 0.001
Craniofacial/head and neck	1.053 × 10 <sup>-4</sup>	NA, 1.770	0.94	1.467 × 10 <sup>-5</sup>	NA, 0.0357	0.944
Other	5.781	2.6444–11.255	< 0.001	7.057	4.961–9.812	< 0.001

NA, value of less than 10<sup>-10</sup>.

longer [relative risk (RR), 1.01 (95% CI, 1.005–1.013)] and for non-insulin-dependent diabetics was 2.04 days longer compared with nondiabetic patients (Table 8). More specifically, the average hospital stay of an insulin-dependent diabetic was 2.09 days (SD, 9.18), a non-insulin-dependent diabetic was 4.03 days (SD, 12.59), and for a nondiabetic it was 1.98 days (SD, 8.81).

**DISCUSSION**

The aim of this study was to objectively quantify the complications associated with diabetes mellitus in plastic surgery procedures. With the inclusion of 39,475 plastic surgery patients as well as a national representation of pa-

tients by using the American College of Surgeons NSQIP (ACS-NSQIP) database, this study is the largest known study systematically examining the link between diabetes mellitus and plastic surgery outcomes. We found that only insulin-dependent diabetics had a higher likelihood of surgical complications (IDDM: OR, 1.78; P value < 0.0001; NIDDM: P value < 0.103), whereas both insulin-dependent and non-insulin-dependent diabetics had increased likelihoods of medical complications (IDDM: OR, 1.63; P value < 0.001; NIDDM: OR, 1.44; P value = 0.0093) compared with nondiabetics. Our data corroborate the findings by Bamba et al.,<sup>24</sup> who studied diabetes as an independent risk factor for major complications following aesthetic sur-

**Table 7. Logistic Regression Analysis of the Effect of NIDDM on Wounds following Plastic Surgery Procedures, Categorized According to CPT Grouping Classifications**

CPT Categorization	Wound Dehiscence			Wound Infection		
	OR	95% CI	P	OR	95% CI	P
Breast reconstruction—autologous	2.239	0.668–5.621	0.13	1.082	0.487–2.067	0.83
Breast reconstruction—implant-based	8.983 × 10 <sup>-6</sup>	NA, 0.00535	0.93	0.975	0.381–2.031	0.95
Reduction mammoplasty	0.846	0.138–2.737	0.82	1.356	0.768–2.213	0.26
Other breast procedure	8.983 × 10 <sup>-6</sup>	NA, 0.0350	0.94	1.046	0.409–2.181	0.92
Abdominal procedure	1.903	0.456–5.344	0.29	4.227	2.701–6.366	< 0.001
Hand/upper extremity	3.171	0.1679–18.577	0.29	1.319	0.320–3.614	0.64
Lower extremity	0.793	0.0443–3.751	0.82	2.668	0.791–6.788	0.07
Craniofacial/head and neck	4.757	0.718–18.999	0.049	2.483 × 10 <sup>-5</sup>	NA, 0.00281	0.91
Other	2.429	0.9294–5.256	0.041	2.091	1.275–3.240	0.01

NA, value of less than 10<sup>-10</sup>.

**Table 8. Negative Binomial Model of Length of Hospital Admission**

Variable	Length of Admission Mean (SD)	Rate Ratio	P
Length of Hospital Admission			
IDDM	2.09 (9.18)	1.01 (1.005–1.013)	3.23E-08
NIDDM	4.03 (12.59)	1.01 (1.002–1.013)	8.38E-03
Nondiabetic	1.98 (8.81)	Comparison Group	Comparison Group

Analysis has been adjusted for sex, race, age group, operation year, CPT code, BMI, history of congestive heart failure, use of antihypertensives, renal failure (not requiring dialysis), renal failure requiring dialysis and dyspnea.

gery. In a prospective cohort of 129,007 patients, Bamba et al.<sup>24</sup> found diabetics had a higher rate of complications (3.1%) compared with nondiabetics (1.9%; *P* < 0.01). Very few studies to date have examined the effects of diabetes on surgical outcomes, irrespective of surgical subspecialty. Therefore, our data provide a useful reference point for future studies investigating complications associated with surgery in diabetic patients.

Given the increasing prevalence of diabetes mellitus in the United States, impacting almost 10% of the population, it is important to consider the social determinants of health on endocrine care for diabetics in this type of analysis.<sup>25–30</sup> Recently, Walker et al.<sup>25</sup> published a holistic review of the social determinants of health on the endocrine care that diabetic patients are provided, emphasizing the pervasive gap in care seen especially in the rural south. Walker et al.<sup>25</sup> discussed strong evidence that race, ethnicity, and social determinants of health differences continue to persist in the clinical outcomes for diabetes, including glycemic, blood pressure, and lipid control, and yet these disparities are largely ignored.<sup>25</sup> Interestingly, glycemic control and quality of life for diabetics were shown to be consistently associated with psychosocial factors, namely depression, social support, perceived stress, and neighborhood factors.<sup>25</sup> Hence, the socioeconomic and psychological inequalities related to diabetes care are crucial considerations in preoperative surgical decision making and patient counseling on expectations.

As a comorbidity in surgical patients, diabetes mellitus had a profound impact on plastic surgery outcomes in our cohort. In particular, insulin-dependent diabetic patients had a higher likelihood of wound complications (OR, 1.53; *P* < 0.001) than nondiabetic patients. However, having non-insulin-dependent diabetes was not associated with wound complications (*P* value = 0.112). More

specifically, the odds of an insulin-dependent diabetic having wound dehiscence was 2.05 times (95% CI, 1.27–3.20; *P* value < 0.0023) that of a nondiabetic, and the odds of an insulin-dependent diabetic having a wound infection (which includes superficial wound occurrences as well as deep incisional surgical site infection occurrences) was 1.55 times (95% CI, 1.18–2.02; *P* value < 0.0012) that of a nondiabetic. Moreover, wound subgroup analyses further identified that having non-insulin-dependent diabetes was not significantly associated with wound dehiscence (*P* value = 0.8023) or wound infection (*P* value = 0.066). With regard to breast reconstruction, Hart et al.<sup>31</sup> found that diabetic patients had a significantly higher incidence of delayed wound healing following implant-based reconstruction (OR, 2.52). However, this significant association was not seen with autologous reconstruction (OR, 0.97) in the cohort of 1,371 breast reconstructions performed in 1,035 patients as described by Hart et al.<sup>31</sup> This difference in outcomes from our ACS-NSQIP data could potentially be attributed to their smaller patient cohort reflecting a single institutional experience, and thus, further highlights the importance of a large national study to examine diabetes across a number of plastic surgery procedures. Moreover, with respect to large studies quantifying the risk of infections in diabetic patients, Shah and Hux<sup>32</sup> determined that the risk of nearly every type of infection studied was higher among patients with diabetes, with the highest risk ratios seen for osteomyelitis (RR = 4.39; 95% CI, 3.80–5.06), sepsis (RR = 2.45; 95% CI, 2.23–2.68), postoperative infections (RR = 2.02; 95% CI, 1.80–2.27), and cellulitis (RR = 1.81; 95% CI, 1.76–1.86). Strikingly, in our cohort, IDDM was significantly associated with highly increased surgical, medical, and wound complications in abdominal procedures, hand/upper extremity, lower extremity, and other namely aesthetic procedures and those

classified in the aforementioned “other” category compared with nondiabetics Table 4 (all OR > 3.0). Overall, our large data set provides compelling data to support the significant difference in risks associated with plastic surgery procedures for different diabetic patients, namely insulin-dependent diabetic patients compared with non-insulin diabetic patients. Our analyses demonstrate objective data to support that preoperative counseling should be different for insulin-dependent diabetic patients versus non-insulin diabetic patients, as all diabetes mellitus is not to be generalized as one risk factor.

Furthermore, our study revealed that the average hospital LOS for insulin-dependent diabetics was 0.11 days longer [RR, 1.01 (95% CI, 1.005–1.013)] and for non-insulin-dependent diabetics was 2.05 RR 1.01 (95% CI, 1.002–1.013) days longer compared with nondiabetic patients. Yang et al.<sup>33</sup> in a collaborative effort published a study quantifying the economic burden of diagnosed diabetes, increased health resource use, and lost productivity associated with diabetes in 2012. Interestingly, Yang et al.<sup>33</sup> reported that of the projected 168 million hospital inpatient days in the United States in 2012, an estimated 43.1 million days (25.7%) are incurred by people with diabetes, of which 26.4 million days are attributed to diabetes. In fact, diabetes contributed to longer hospital LOS regardless of the reason for admission, even while controlling for other factors that affect hospital LOS.<sup>33,34</sup>

Comparatively, with respect to the effect of diabetes on surgical subspecialty outcomes and LOS, Maloney et al.<sup>35</sup> found that mean LOS was significantly longer in diabetic patients (1.9 versus 1.4 days;  $P < 0.0001$ ) undergoing neurosurgery, namely open lumbar microdiscectomy procedures. Likewise, in the otolaryngology literature, Rairkunda et al.<sup>36</sup> demonstrated that diabetic patients had longer LOS following facial fracture repair in a large cohort of 45,509 inpatients using the Nationwide Inpatient Sample database. Additionally, Bur et al.,<sup>37</sup> using the ACS-NSQIP dataset, reported that diabetes was a clinical factor independently associated with unplanned readmission within the first 30 days postoperatively following head and neck surgery for malignant neoplasms. Thus, our results substantiate national diabetes data as well as data reported by surgical subspecialties on hospital LOS. Future studies conducting cost analyses on hospitalization of diabetic patients undergoing a range of plastic surgery procedures are warranted.

Finally, given these results examining the effect of diabetes mellitus on outcomes in a wide spectrum of plastic surgery procedures, it is crucial to acknowledge that multiple approaches exist for preoperative and perioperative glucose control. Recently, Dortch et al.<sup>38</sup> published an example of a practical approach to perioperative blood glucose management based on current guidelines set by the Endocrine Society and Mayo Clinic Institutional Protocol. These guidelines are based on preoperative hemoglobin A1C levels and vary depending on whether surgery is inpatient or out-patient, and elective or urgent. Ultimately, our data provide a compelling impetus and foundation upon which to consider national glucose management guidelines for plastic surgeons for this high risk patient

population. In fact, a future study focusing on perioperative glucose management and the development of a widely applicable algorithm would be a great resource for clinicians, as the plastic surgery literature is lacking on this topic.

#### Study Limitations

Although this study has systematically presented a quantified association between diabetes and postoperative outcomes for a wide range of plastic surgery procedures using the largest cohort to date, the study has certain limitations that merit discussion. First, this study cohort is compiled from the NSQIP database, which is predicated upon all procedures being entered and available in the database. Second, a disadvantage to the use of this NSQIP database is that the resultant study is retrospective in nature, and the database does not provide robust clinical information, namely specifics of the nature of each procedure collated by CPT code or hemoglobin A1c values for diabetic patients. Finally, our study lacks the ability to extrapolate long-term complication data for diabetic patients undergoing plastic surgery procedures, as the follow-up period for NSQIP is limited to 30 days postoperatively from each procedure. For example, by limiting postoperative data collection to 30 days, the database does not capture certain complications that are important to plastic surgeons, such as capsular contracture rates, keloid and hypertrophic scar formation, and long-term pain.

## CONCLUSIONS

Diabetes, especially IDDM, increases a multitude of postoperative complications, and the overall risk profile of patients undergoing plastic surgery, as demonstrated in this large analysis. The negative consequences of diabetes status on outcomes following plastic surgery can be used to counsel patients on the importance of optimizing preoperative diabetes management, particularly glycemic control, and to enhance perioperative decision making while risk stratifying based on type of plastic surgery procedure to be performed. Ultimately, given the full spectrum of plastic surgery procedures included in this study, these results have wide-scale applicability to the specialty and enable plastic surgeons to provide diabetic patients with tangible, quantifiable complication risks for the specific procedures they undergo.

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